

THE WEATHER AND CIRCULATION OF AUGUST 1960

A Month Dominated by a Circulation Reversal

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1. CONTRASTING CIRCULATION PATTERNS WITHIN THE MONTH

A major reversal in the large-scale 700-mb. mean circulation over North America and adjacent oceans occurred from the first half to the last half of August 1960. This intra-monthly change contributed substantially to the weather and circulation of the whole month. It is particularly notable because summer months are generally subject to considerable persistence. Consequences of the intra-monthly circulation change included a readjustment of the weather anomalies both within the month and from the preceding month.

AUGUST 1-15

The 15-day mean circulation for the first half of August, shown in figure 1A, clearly indicates a pattern of four rather symmetrical cyclonic vortices in the Northern Hemisphere. Three were located around 60° N., but the fourth (over Asia) was 10° farther north. The wave number at middle and lower latitudes was greater by at least one, but not so well defined.

An interesting observation concerning the cyclonic vortices is derived from the anomalous height distribution at 700 mb. (dotted lines in fig. 1A). First, note the intensity of the Low centers. Beginning with the -170-ft. center over the Bering Sea, and continuing in a clockwise direction, the negative anomalous height centers become progressively deeper, with maximum intensity (-340 ft.) over Quebec.

Of further note are the wavelengths involved. There was a gradual but definite increase in the wave spacing, beginning with the trough in the north central Pacific, and moving in a clockwise direction. At 55° N. there was a wavelength of 115° of longitude from the trough in eastern North America to the next trough upstream in mid-Pacific. The blocking in polar latitudes centered over northern Greenland undoubtedly influenced the asymmetry of the pattern and in some manner probably contributed to the unusual wave spacing.

The western lobe of the subtropical ridge in the Pacific was quite strong (+210 ft.) and displaced some 5° of latitude northward from the August normal [1]. The eastern portion of the ridge was also higher than normal, and displaced northward a similar amount. The trough

in the central Pacific was deeper than normal at higher latitudes and much weaker at middle latitudes. Another item of interest was the rather strong ridge in western Canada, which was directly north of a weaker-than-normal trough along the west coast of the United States.

AUGUST 16-31

A comparison of the 700-mb. circulation of the last half of August (fig. 1B) with the first half (fig. 1A) reveals most impressive changes, especially over North America. Strong deepening in western North America was apparently resonant with amplification in the Pacific. Contributory to or sustaining the anticyclogenesis in the western Pacific was intense low-latitude activity in the southwestern Pacific.

In retrospect, cyclogenesis in western North America was a logical development. Since the wavelength from eastern North America to the central Pacific was extremely long, and since the westerlies appeared too weak to support that wavelength, an untenable situation developed. Accommodation occurred in the form of a new, full-latitude trough in western North America. Downstream, the trough over eastern North America was replaced by a ridge; the ridge in mid-Atlantic moved east as a trough took its place during the last 15 days of August.

The result was a succession of intra-monthly height changes of alternating sign from eastern Asia eastward to Europe (fig. 1C). Maximum negative and positive changes in the Northern Hemisphere were contiguous over North America, with a -530-ft. height fall near Great Slave Lake and an opposing height rise of 380 ft. in Quebec. Note that as dispersion operated eastward from North America, progressive damping occurred in the magnitude of centers of height rise and fall.

The deepening trough in western North America is noteworthy not only as an anomaly of the planetary wave system, but also because of the accompanying temperature modification in the United States.

2. CONTRASTING TEMPERATURE PATTERNS IN AUGUST

Temperatures in the United States were subject to an oscillation from the first half of August to the last half, parallel to the circulation changes described above.

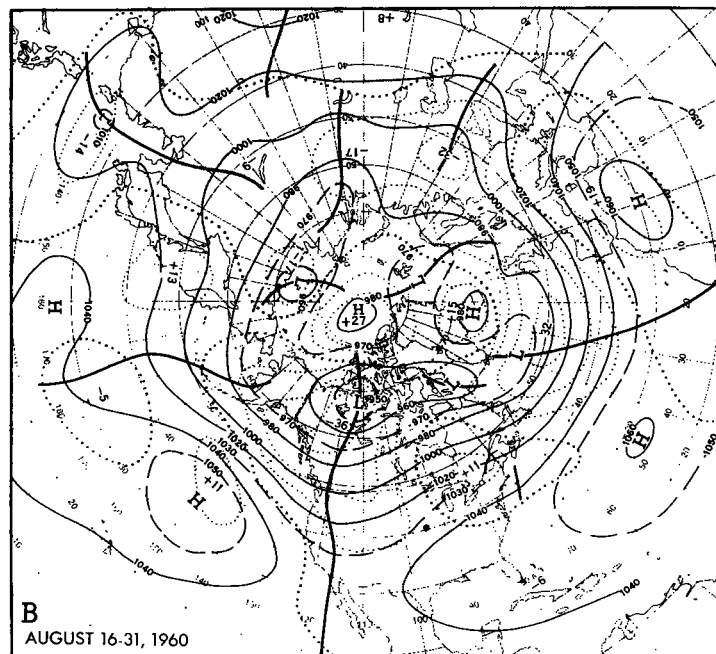
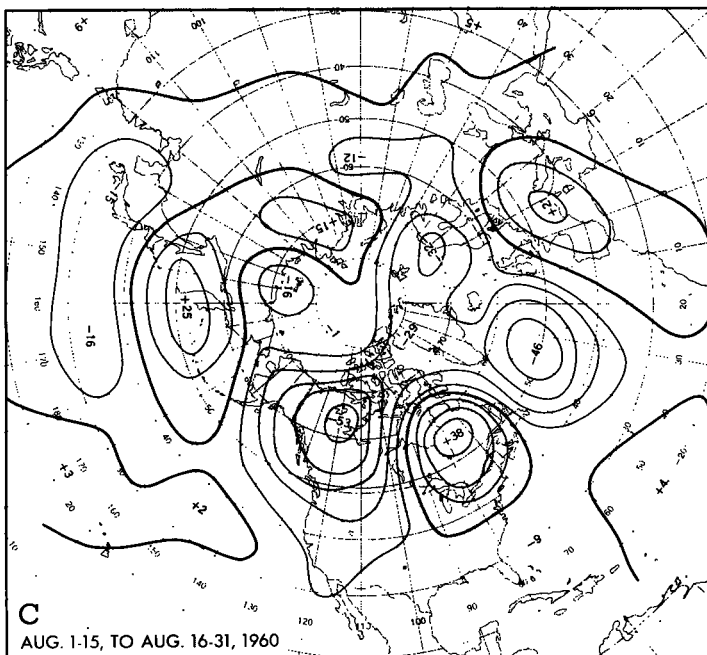
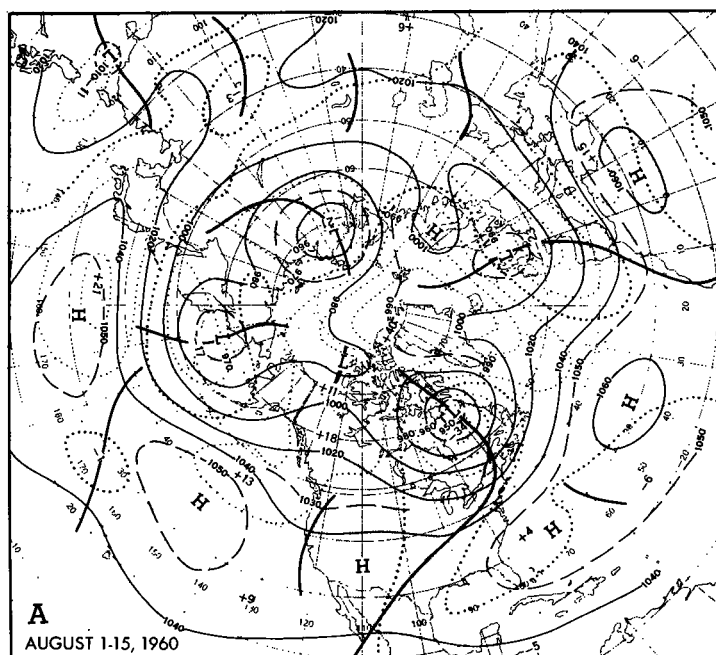


FIGURE 1.—Mean 700-mb. contours (solid) and height departures from normal (dotted) (both in tens of feet) for (A) Aug. 1–15, 1960, and (B) Aug. 16–31, 1960; (C) 700-mb. height change (tens of feet) from (A) to (B). The —530-ft. change near Great Slave Lake reflects the intense deepening in western North America.

weakness of the mean trough there, it is somewhat surprising that temperatures were not higher.

In the Northeast and throughout the Mississippi Valley, temperatures were as much as 4° F. cooler than normal. They were aligned approximately along the zone of below normal heights in and near the mean trough which extended from the Low over the Ungava Peninsula through New England to Texas. In the Middle Atlantic States warmer than normal temperatures coincided with a relatively strong westward extension of the Bermuda ridge.

AUGUST 16-30

Extreme cooling in the West from the Canadian Border to Mexico during the last half of August (fig. 2B) was directly related to the intense cyclogenesis at 700 mb. (fig. 1B). Stronger than normal northwesterly flow was responsible for several invasions of cool Pacific air masses west of the Continental Divide.

Temperature changes from the first half of August to the last half ranged as much as -6° to -8° F. (fig. 2C), as cooler than normal temperatures were widely reported from Arizona to Washington (fig. 2B). New daily minimum temperatures were recorded at several stations in the Northwest, following the injection of unseasonably cold air. An extreme example of the change of temperature regime was at Burns, Oreg., where a daily mean temperature of 78° F. was observed on August 12; on August 22, the daily mean was 46° F.

In response to the deepening trough in the West, a

AUGUST 1-15

Temperature departures from normal for the first 15 days of August are shown in figure 2A. It was very hot in the Southwest with much of northeastern Arizona at least 6° F. above normal. The heat in the Southwest was accompanied by a quasi-stationary anticyclone at 700 mb. (fig. 1A), abundant sunshine, and prolonged subsidence. Little cooling was realized from the northerly direction of the anomalous component of the upper level flow. This flow was effective, however, in the Pacific Northwest where a few stations from Montana to northern Oregon reported temperatures slightly below normal. Considering the

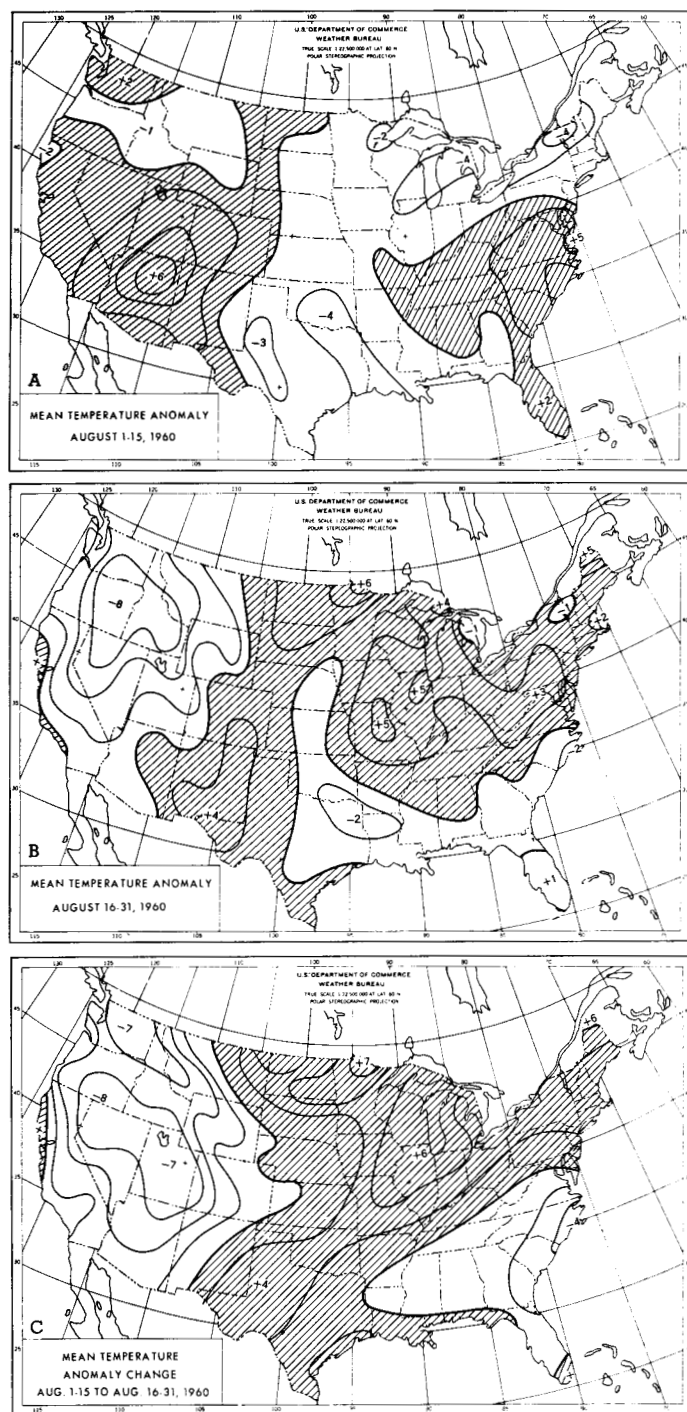


FIGURE 2.—Departure of average surface temperature from normal ($^{\circ}\text{F}$) for (A) Aug. 1–15, 1960 and (B) Aug. 16–31, 1960; (C) temperature change ($^{\circ}\text{F}$) from (A) to (B). Cooler air in the last half of August dominated the West from the Canadian border to Mexico.

general warming occurred immediately to the eastward. At International Falls, Minn., the daily mean temperature increased by 24°F . from August 14 to August 17. Warming in other areas was less spectacular, but rather general, east of the Rockies, except in the Southeastern States.

Some cooling occurred in the Southeast in the last 15 days of the month (fig. 2C), but it was neither of the same magnitude nor extent as the cooling and warming just described, principally because changes in the circulation were slight (fig. 1C). It may seem contradictory that cooling should occur under the mean ridge observed in the Southeast (fig. 1B). However, upper-level heights were below normal; there were also cooling effects of the onshore direction of the anomalous height component.

3. MONTHLY MEAN WEATHER ANOMALIES

TEMPERATURE

The departure of average temperature from normal for the month of August (fig. 3A) was similar in pattern to that observed during the last half of August (fig. 2B). Thus, the character of the change in the last 15 days was so intense that it effectively determined the distribution of temperature anomalies for the whole month.

Cold air in the West penetrated as far south as the lower San Joaquin Valley, but maximum departures from normal were centered in Idaho. New low temperatures for August and new daily minima were recorded in the Pacific Northwest at several stations. A daily mean temperature 19° below normal at Pocatello, Idaho, on August 16 is an extreme example of the cooling in that area.

Opposed to the cold in the Northwest was the continued warmth in the desert areas of the Southwest. Temperatures were not particularly abnormal, but persistently warm. August was the third successive month of warmer than normal conditions. A report from Winslow, Ariz., stated that daily maximum temperatures were 90°F . or more for 28 consecutive days, a new 30-year record.

Another belt of warm conditions from the Ohio Valley eastward to the Middle Atlantic States prevailed with little variation during August. Norfolk, Va., for example, was warmer than normal on 24 days of the month and had a mean temperature departure of $+3.6^{\circ}\text{F}$.

From Nebraska to eastern Texas, thence eastward to Florida, cooler than average weather generally prevailed, but departures from normal were less than 2°F .

Since August was a particularly non-persistent month, it is appropriate to compare the temperature anomaly of August (fig. 3A) with that of July (fig. 3B). Warm air in the West in July was replaced in August with fairly cool air; a similar reversal took place on the Gulf Coast; cool weather in the East in July became warmer than normal in August; and from the Dakotas to the Southwest little change occurred.

The lack of persistence of temperature anomalies from July to August is best seen in figure 4. This figure represents the number of temperature class¹ changes from July to August at 100 stations. The unshaded

¹ Temperature anomalies are divided into the following classes: much above and much below ($12\frac{1}{2}$ percent occurrence each) and above, near normal, and below (25 percent occurrence each).

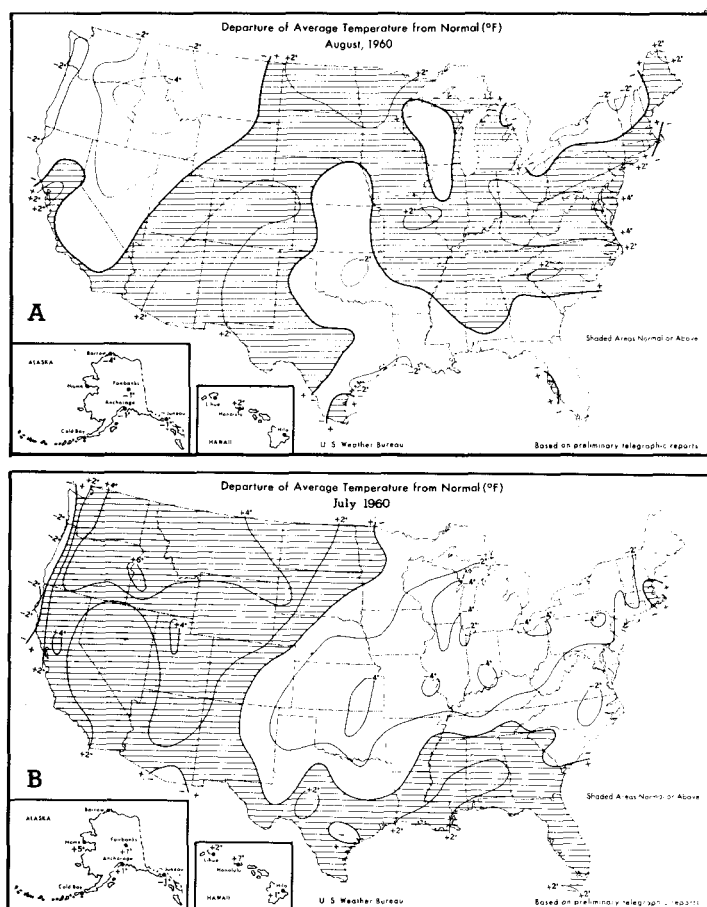


FIGURE 3.—Departure of average surface temperature from normal ($^{\circ}\text{F}.$) for (A) August 1960, and (B) July 1960. Hatching shows area of warmer than normal anomalies; unshaded areas were cooler than normal. Note general reversal of pattern from July to August. (From [8].)

portions of the map include those stations which reported a change of no more than one temperature class, thus delineating areas of relative persistence from July. A broad area in the Northwest (stippled) was two to four classes colder in August than in July. Also colder was the Gulf Coast, by two to three classes. The hatching portrays a warming of two to three classes. The area of warming was centered in the Ohio Valley and was roughly equivalent in size to the areas of cooling. Quantitatively, there was little difference between the two since 19 stations cooled two or more classes and 18 stations warmed by the same amount from July to August.

A tabulation of temperature class changes indicates a temperature persistence index of 63 percent, compared with a 16-year average of 82 percent for August [2]. It should be noted that persistence of 54 percent in August 1959 was particularly low, as was an index of 59 percent in August 1958. Thus, 1960 marked the third consecutive year in which July-August persistence of monthly mean temperatures has been subnormal.

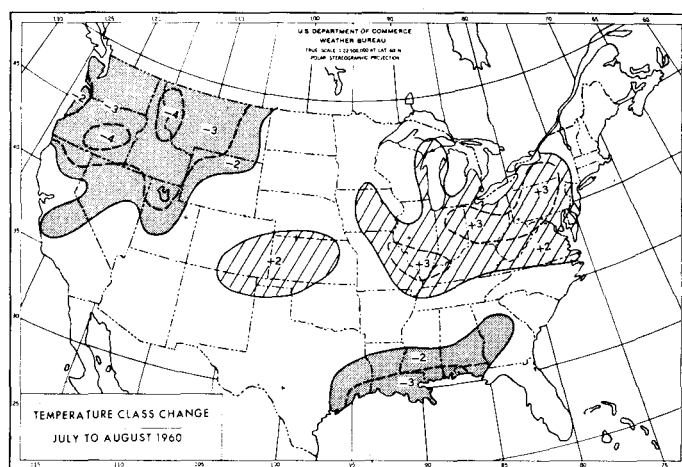


FIGURE 4.—Change in class of temperature anomalies from July 1960 to August 1960. In unshaded areas temperatures did not change by more than one class (out of five); hatched areas represent a warming of two or more classes; and stippled areas show cooling of two or more classes. Largest changes were in the Northwest where temperature anomalies changed from much above normal in July to much below normal in August.

Non-persistence of temperatures in August resulted principally from intra-monthly changes in the circulation. But the effects of the variability in the circulation were not confined to temperature; the distribution of precipitation was also influenced.

PRECIPITATION

Precipitation in several sections of the United States in August was much greater than normal (fig. 5). August rains alleviated drought in parts of Montana and Wyoming, but paradoxically southern Wyoming remained dry. Farther west, at Stampede Pass, Wash., a total of 5.06 in. of rain established a new August record, all but 0.08 in. of which fell in the last 18 days of the month. Most of the precipitation in the Northwest was associated with the deepening trough discussed above and illustrated in figure 1B.

No measurable rain was reported over much of California, and dry conditions extended as far east as western Kansas, where Goodland had only 0.29 in., the driest August of record.

Above normal precipitation in the Great Plains was coincident with a deep southerly mean flow of tropical Gulf air at sea level (Chart XI of [3]). In the Northern Plains both fronts and cyclone passages were frequent. Yet, actual amounts of rain were much greater in the Southern Plains, presumably a result of more widespread convection.

The maximum monthly precipitation (from early reports) fell at Vicksburg, Miss. The total was 16.58 in., of which 6.20 fell in one day. That station experienced the wettest August of all time and the wettest month

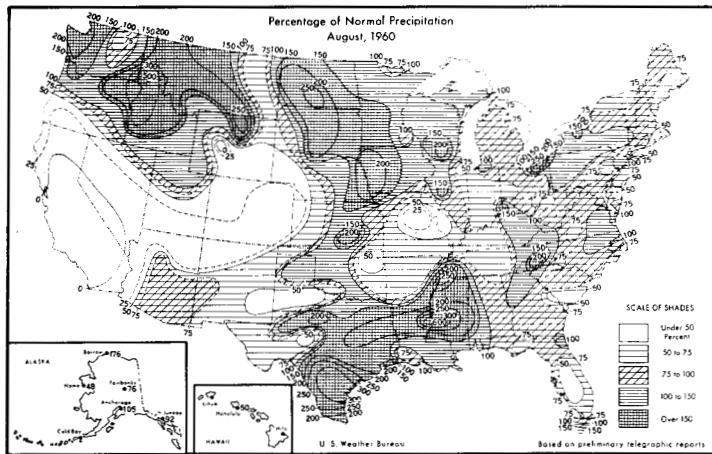


FIGURE 5.—Percentage of normal precipitation for August 1960. Above normal rainfall in the North was associated with frequent frontal activity. (From [8].)

since October 1918. Port Arthur, Tex. also had the wettest August of record with a total of 14.48 in.

4. MONTHLY MEAN 700-MB. CIRCULATION

The monthly mean circulation in the mid-troposphere (fig. 6) was dominated to a great extent by relatively strong blocking in polar latitudes. Characteristic of such widespread blocking was the expansion of the circumpolar vortex, indicated by an almost unbroken ring of negative height anomalies from 50° to 60° N. The eccentricity of blocking on the occidental side of the Pole produced southward displacement of the temperate westerlies in eastern North America, the Atlantic, and Europe. In most of Asia and the Pacific, on the other hand, the westerlies were farther north than normal.

Considering only the area from 0° to 180° in an east to west direction, the average latitude of the maximum temperate westerlies was near 45° N., the same as normal for August. Thus, the opposed displacement of the temperate westerlies, i.e., to the north in the Pacific and to the south in the Atlantic, had a canceling effect in the mean. The average speed of the temperate westerlies was 2.2 m.p.s. faster than normal, a considerable deviation to be sustained for the whole month.

In the Pacific there is normally considerable persistence in circulation features from July to August [1]. This year, however, there was little resemblance in the two months. In July the circulation was composed of a trough off Japan and another in the Gulf of Alaska [4]. Figure 7 emphasizes the changes that took place in the succeeding month. Height rises in the eastern and western Pacific and falls between resulted in the August pattern of only one trough in the Pacific.

Over North America the circulation was similarly non-persistent as deepening in the West and filling in the East essentially reversed the pattern. There was little change

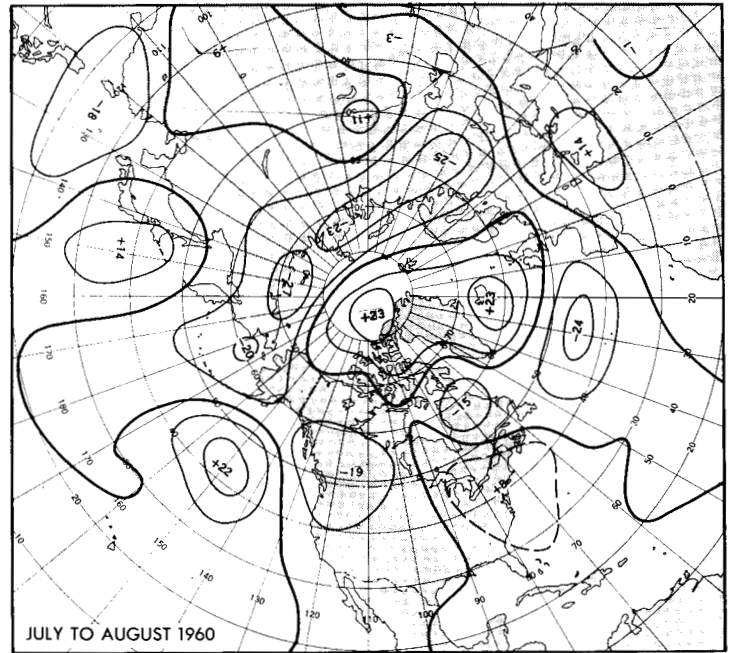


FIGURE 6.—Change in 700-mb. height departures from normal (tens of feet) from July 1960 to August 1960. The reversal of long-wave features at middle latitudes is especially apparent from Europe westward to eastern Asia.

in the configuration of the circulation in the Atlantic; but principal features became more intense, especially the blocking over southern Greenland.

From Europe eastward the succession of waves in the westerlies was rather chaotic, but not at all unrealistic for summertime. The relatively short wavelengths from the eastern Atlantic to eastern Asia were in distinct contrast to those in the Pacific and North America.

Of particular interest was the strength of the tropical easterlies in the Pacific. While the temperate westerlies were 2–4 m.p.s. stronger than normal in a west-to-east belt from Hokkaido to the west coast of the United States, the tropical easterlies were 2–5 m.p.s. higher than normal from 180° to the East China Sea. The unusual speed of the tropical easterlies was explicitly related to above normal heights east of Japan and intense cyclonic activity in the tropical Pacific.

5. TROPICAL STORMS

An incomplete summary of available data indicates that the frequency of tropical storms in the western Pacific in August 1960 was unprecedented [5,6]. A total of eleven storms was reported during the month, of which nine reached typhoon intensity. In 1925 and again in 1942 there were nine tropical storms in August, probably the previous record. There are several average values by several authors, but it seems that a normal frequency of tropical storms in August would lie between 4.0 and 4.5.

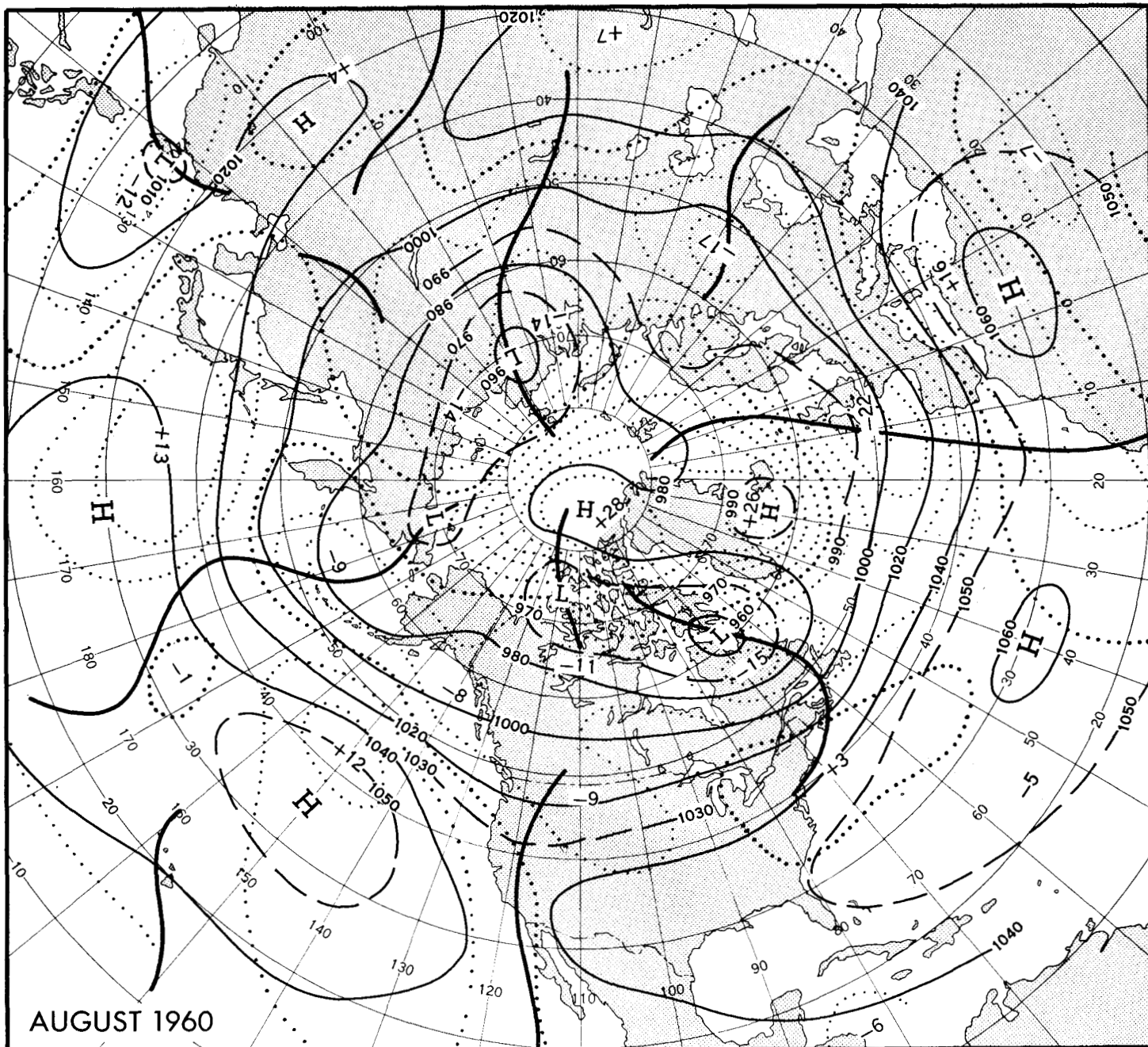


FIGURE 7.—Mean 700-mb. contours (solid) and height departures from normal (dotted) (both in tens of feet) for August 1960. Dominance of polar blocking is revealed by the large area of above normal heights near Greenland.

Grossly smoothed tracks taken from storm bulletins are shown in figure 8. Dashed lines are tracks of storms which did not reach typhoon intensity; solid lines are tracks of storms which were classified as typhoons at some point in their life history. Additional data on the storms shown in figure 8 are given in table 1.

The unusual tropical storm activity is well indicated on the monthly mean 700-mb. chart (fig. 6). Note especially the Low center over Taiwan and the stronger than normal

southeasterly flow between this Low and the High south-east of Japan. Even though seven of the nine typhoons recurved, the monthly mean 700-mb. chart does not clearly reflect the recurvature (i.e., a strong polar trough) as emphatically as it does the locus of activity preceding recurvature. A fundamental reason is the greater speed of tropical storms after recurvature than before. A count of preliminary positions of storms which recurved indicates that between latitudes 20° and 30° N. tropical

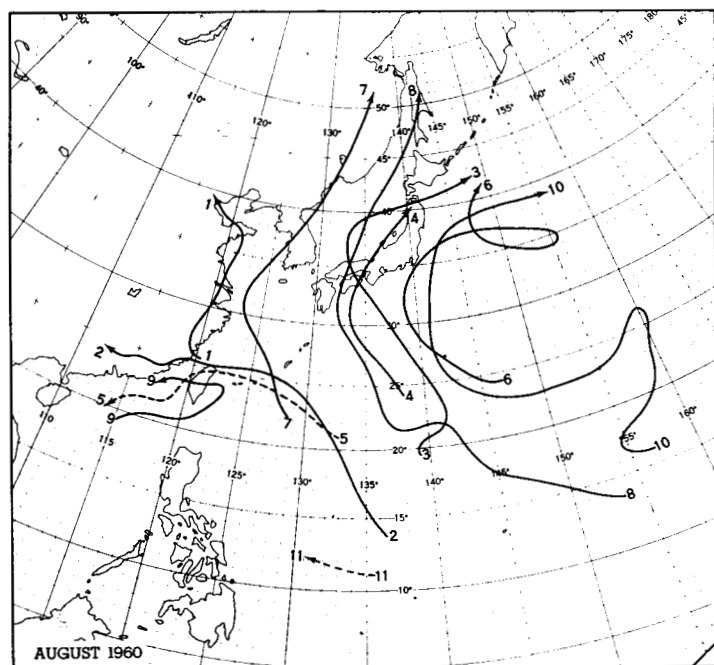


FIGURE 8.—Smoothed tracks of tropical storms in the western Pacific for August 1960. Tracks are numbered chronologically. Solid lines represent those storms which reached typhoon intensity; those which did not are shown as dashed lines. (See table 1.)

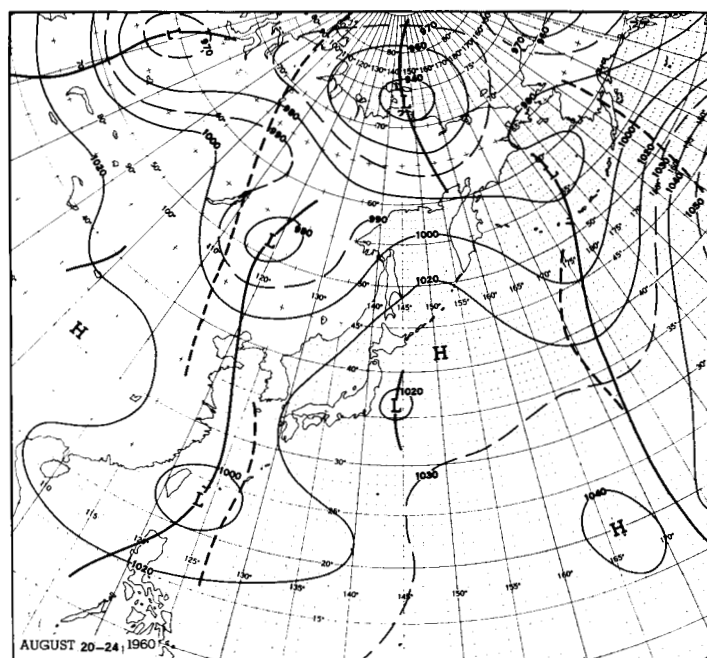


FIGURE 9.—Five-day mean 700-mb. chart for August 20-24, 1960. (Contours in tens of feet). Heavy solid lines are current trough positions; heavy dashed lines are positions of troughs for the period August 16-20, 1960. The amalgamation of polar and tropical troughs was concurrent with maximum typhoon activity.

storms were present on 28 out of the 31 days in August, while between 30° and 40° N. there were only 16 days with tropical storms.

Maximum tropical storm activity occurred in the 5-day period from August 20-24 (see table 1). On each of those five days there were four or five storms in various stages of development or decay. The 5-day mean 700-mb. chart for that period (fig. 9) shows a connection between the polar Low east of Lake Baikal and the tropical Low near Taiwan. It appears that the proximity of the polar trough increased the probability of recurvature. If the polar trough had not been progressing eastward as the easterly trough was moving westward (see heavy dashed lines), or if the polar trough had not been in existence, it

is probable that tropical activity would have been inhibited instead of encouraged.

There were two hurricanes in the eastern Pacific in August. Diana was found near 15°N., 99°W. on August 16 and dissipated after striking the tip of Baja California on August 19. On the last three days of the month hurricane Estelle moved west-northwestward from an initial position near 11°N., 90°W. but did not hit land.

Opposed to the high frequency of tropical storms in the western Pacific was the single tropical disturbance in the Atlantic. Hurricane Cleo was first detected northeast of the Bahamas on August 18 and moved north-northwestward off the east coast of the United States thereafter with little damaging effect. Cleo became extratropical near Nova Scotia on August 21.

TABLE 1.—Tropical Storms in the Western Pacific, August 1960. (Data from [7].)

Number	Name	Dates	Maximum wind speed (kt.)
1	Shirley	1-5	125
2	Trix	4-9	135
3	Virginia	8-11	90
4	Wendy	11-12	65
5	Agnes	12-15	55
6	Bess	16-24	70
7	Carmen	16-23	75
8	Della	17-30	105
9	Elatne	20-24	80
10	Faye	22-31	135
11	Gloria	30-31	40

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